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PREPOZNAVANJE SPOLA PREMA RUKOPISU

GENDER RECOGNITION BASED ON HANDWRITING

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SAŽETAK

Povezanost spola i rukopisa istražuje se već preko stotinu godina, stoga je relativno velik broj istraživanja ove teme ukazao na postojanje mogućnosti da se spol autora identificira prema rukopisu. Ovaj je rad dodatno istražio ovu poveznicu uzevši dob autora rukopisa i dob osobe koja pogađa spol prema rukopisu kao dodatne varijable. Ispitanici su podijeljeni u šest kategorija ovisno o spolu i dobi te se točnost u pogađanju spola prema rukopisu analizirala skupno i zasebno za svaku pojedinačnu kategoriju. Kroz dvadeseto je stoljeće povezanost spola i rukopisa bila uglavnom proučavana u domeni psihologije i kriminalistike, dok se odnedavno počela redovito proučavati u mnogim drugim disciplinama kao što su strojno učenje, neurologija i endokrinologija. Dosadašnji su radovi pokazali da je moguće u određenoj mjeri točno pogoditi spol autora prema rukopisu, dok visoka točnost umjetne inteligencije u pogađanju spola prema rukopisu implicira da je poveznica između spola i rukopisa ne samo stvarna već i velika. Rezultati ovog rada pokazali su tipičnu točnost ispitanika u pogađanju spola prema rukopisu, a također ukazuju i na to da je dob autora rukopisa postojeća varijabla s obzirom na to da su ispitanici u ovom pokusu neovisno o spolu i dobi točnije pogađali spol mlađim autorima rukopisa.

Ključne riječi: *spol, rukopis, dob*

ABSTRACT

The connection between gender and handwriting has been studied for over a hundred years and there is a significant number of papers written on this topic. This paper further investigated this connection by introducing the age of the manuscript author and the age of the person guessing the gender from the manuscript as additional variables. Respondents were divided into categories depending on gender and age, and accuracy in guessing gender according to handwriting was observed. Previous work has shown that humans can correctly guess the gender of the author from the handwriting to a certain extent, and the relatively high accuracy of artificial intelligence in guessing the gender from the handwriting implies that the link between gender and handwriting is not only real but also large. The results of this work showed the typical accuracy of the respondents in guessing the gender according to the handwriting, and also indicate that the age of the manuscript author is an existing variable, considering that the respondents in this experiment, regardless of gender and age, guessed the gender of younger manuscript authors more accurately.

Keywords: *gender, handwriting, age*

1. UVOD
1. INTRODUCTION

Despite the relatively large number of existing studies on this topic, the relationship between gender and handwriting remains insufficiently explained to this day. In an era increasingly focused on gender and sex diversity, insight into this subject provides a foundation for a deeper understanding of cognitive differences between the sexes.

This paper examines the connection between

biological sex and handwriting, with the main objective of determining how accurately people can infer a person's sex based on their handwriting. Similar studies have been conducted several times before and are used here as a basis for comparison and consistency verification. Although some earlier studies were carried out roughly a hundred years ago in different cultures (and thus on speakers of other languages), many of the results obtained in this research are consistent with those and other previous findings.

The key questions this study seeks to answer are: With what statistical accuracy can people infer the biological sex of an unknown individual from their handwriting? Do members of one sex perform better, worse, or equally well in recognising handwriting of their own or the opposite sex? And do people of certain age groups better, worse, or equally accurately identify sex from handwriting belonging to their own age group?

After an extensive review of the available literature, a lack of similar studies involving South Slavic language speakers was observed. Although no comparable research has previously been conducted among speakers of South Slavic languages, it is worth mentioning the existence of a comprehensive scientific paper, "Possibilities of Determining the Sex of the Scriptor in Forensic Handwriting Identification" (Kavazović, Bajraktarević Pajević, and Lučić-Ćatić), which addresses this topic within the fields of criminology and graphology.

2. PREGLED LITERATURE
2. LITERATURE REVIEW

2.1. NAJRANIJA ISTRAŽIVANJA
2.1. EARLIEST RESEARCH

The results of one of the earliest studies in this field, conducted by Alfred Binet on a sample of ten subjects, show a mean accuracy of 69.75% [1]. Binet examined the possibility of identifying the author of handwriting through graphological analysis. In a subsequent study investigating gender differences in handwriting, J. E. Downey tested a group of thirteen participants and obtained an average accuracy rate of 67.33% [2] . S. M. Newhall conducted further research into the accuracy of judgements about a person's sex based on handwriting, repeating the experiment twice—first with a sample of 92 participants and later with 79. He also compared the average accuracy of male and female participants and found no significant differences between them. This research yielded slightly lower results: in the first instance, an average accuracy of 57.34% was recorded, and in the second, 57.5% [3]. Goodenough (1945) examined the accuracy of sex identification based on handwriting under different conditions and reported a mean accuracy rate of 69.75%.

2.2. BIHEVIORALNI PRISTUPI I SPOLNI HORMONI
2.2. BEHAVIORAL APPROACHES AND SEX HORMONES

Beech and Mackintosh investigated the influence of sex hormones on handwriting style, considering the digit ratio and gender role identity [4] . Their results suggest that biological factors may have a measurable effect on handwriting characteristics. Conversely, Hartley criticised earlier research on gender differences in handwriting, emphasising the need for greater interpretive caution when analysing such results [5] . His study, conducted with boys and girls, examined how accurately individuals (in this case, children) could identify the writer's sex when the author deliberately attempted to imitate the handwriting style of the opposite sex.

2.3. MULTIKULTURALNI PRISTUPI
2.3. MULTICULTURAL APPROACHES

Hamid and Loewenthal analysed gender recognition from handwriting in different languages (Urdu and English) and concluded that the accuracy of gender estimation varies depending on language and cultural context. Their research highlights the importance of considering cultural variables when analysing handwriting, as well as the influence of gender roles and gender stereotyping [6].

2.4. AUTOMATSKA DETEKCIJA SPOLA PUTEM RUKOPISA, RAČUNALNA OBRADA I ONLINE RUKOPIS

2.4. AUTOMATIC GENDER DETECTION THROUGH HANDWRITING, COMPUTER PROCESSING, AND ONLINE HANDWRITING

Advancements of technology have enabled the use of machine learning algorithms for gender detection based on handwriting. Liwicki et al. researched automatic gender detection using data obtained from both online and offline methods [7]. Saraswat et al. applied deep learning techniques to recognise the gender and dominant hand of handwriting authors [8]. They used models such as CNN, AlexNet, ResNet, GoogLeNet, and VGG, some of which achieved exceptionally high accuracy. Meanwhile, Shin et al. investigated gender recognition based on online handwriting using statistical approaches and machine learning [9].

2.5. PRAVNE I KRIMINALISTIČKE IMPLIKACIJE

2.5. LEGAL AND CRIMINOLOGICAL IMPLICATIONS

Kavazović et al. investigate the possibilities of determining a writer's gender in forensic handwriting identification. Their research demonstrates that handwriting can serve as a useful supplementary method for identifying perpetrators in forensic investigations. This study is also relevant to the present work as it represents the only research on the connection between gender and handwriting in South Slavic languages [10].

2.6. RASPRAVA I BUDUĆE PERSPEKTIVE

2.6. DISCUSSION AND FUTURE PERSPECTIVES

Meena, Krishan, Ghosh, and Kanchan provided a broader literature review that further considers the possibility of gender estimation from signatures and handwriting. They identify the limitations of previous research and offer suggestions for future studies [11] . Yang et al. add a neurological perspective to the topic by investigating differences in brain activation during writing between men and women [12].

3. ISPITANICI I METODE

3. PARTICIPANTS AND METHODS

For this study, 40 authors (21 women and 19 men) from various age groups provided handwriting samples. All wrote the same two sentences: „Moja mama je uvijek govorila da je život kao kutija čokolade. Nikad ne znaš što ćeš dobiti".

It is important to note that these contributors (unlike participants in some earlier studies) were aware of the purpose for which their handwriting would be used, and they had complete freedom in writing (the sentences were dictated orally, they were not instructed to write in print or cursive, and any grammatical errors were disregarded—for example, a few participants wrote „ne znaš" without a space, yet such samples were still included in the study). These 40 handwriting samples were then uploaded to a web survey completed by 1,160 participants (this number does not include a small number of irrelevant samples). All handwriting samples were displayed on the same page, allowing participants to review and change previous answers before finalising in their submission and receiving feedback on accuracy.

Without the researchers' intention, a significantly higher number of women completed the survey (983, or 84.7% of the sample) compared to men. Participants had to confirm they were adults and were informed that the survey had no time limit and did not measure response speed. They were also asked to enter their age and specify their gender (M/F). The participants completing the survey and the contributors providing handwriting samples were not connected in any way and never met. All samples and results were collected anonymously (only the researchers knew the identities of those who provided handwriting). The samples were collected from April to June 2024, while survey results were gathered in the latter half of July 2024.

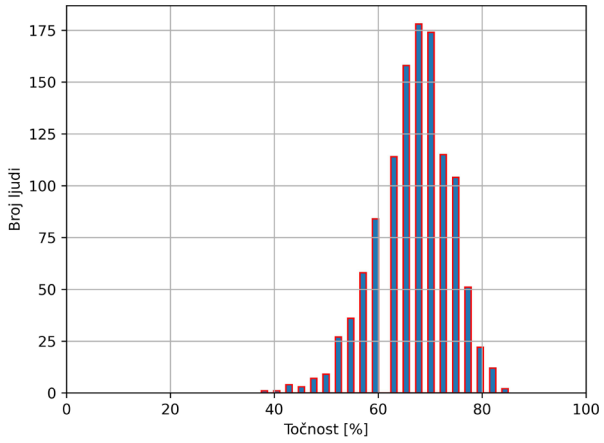
Participants were divided into six groups (men aged 18-30, men aged 31-50, men aged 51-80,

women aged 18-30, women aged 31-50, and women aged 51-80). The collected data were processed statistically—average scores for each gender regardless of age, average scores for each age group regardless of gender, and average scores for each of the six age-gender groups guessing their own and other age groups' gender regardless of participant gender were analysed. Results were then compared with existing findings from previous studies on the relationship between gender and handwriting. The extent to which the writer's age and gender affect the likelihood of correctly guessing their gender based on handwriting was also examined.

4. REZULTATI
4. RESULTS

4.1. OPĆI REZULTATI
4.1. GENERAL RESULTS

As previously noted, some results obtained in this study are consistent with those from earlier research. The greatest similarity is seen in the average accuracy of all participants, which is 66.78% (26.4 points out of a total of 40, with one point representing a correct gender guess for one handwriting sample).



Slika 1 *Postoci točnosti i broj ispitanika koji su ostvarili taj postotak*

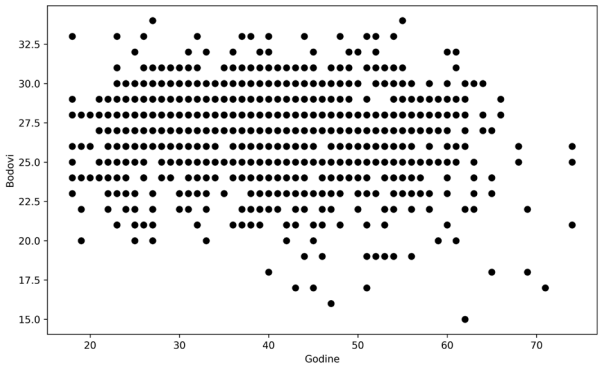
Figure 1 *Accuracy percentages and the number of participants who achieved each percentage*

One of the earliest studies in this field, conducted by Alfred Binet on a sample of ten participants, reported an average accuracy of 69.75%. [1] In a subsequent study by J. E. Downey with thirteen participants, an average accuracy of 67.33% [2] was found. S. M. Newhall conducted research twice (first with 92 participants, then with 79) yielding somewhat lower results—an average accuracy of 57.34% in the first round and 57.5% in the second. [3]

The standard deviation of the average value obtained in this study is 7.15%, while the statistical error is 0.21%. The average value for all participants, regardless of gender and age, is shown in Figure 1.

4.2. DOB I TOČNOST U POGAĐANJU SPOLA PREMA RUKOPISU
4.2. AGE AND ACCURACY IN GUESSING GENDER FROM HANDWRITING

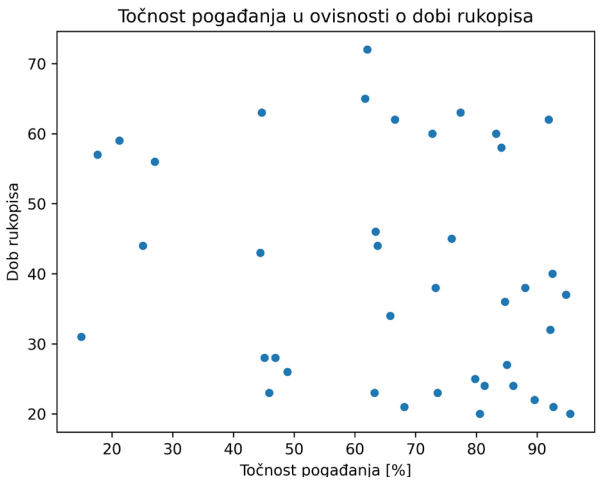
Figure 2 shows a scatter plot correlating participants' age with the accuracy of their guesses. It reveals no significant correlation between participants' age and their ability to infer the gender of an unknown person based on handwriting, except that some participants older than 40 achieved accuracy below 50%, which was rare among those younger than 40.



Slika 2 *Graf raspršivanja uzoraka ovisno o točnosti pogodaka i dobi ispitanika*

Figure 2 *Scatter plot of samples based on guessing accuracy and participants' age*

If the relationship between the age of the person who provided the handwriting sample and the probability of correctly guessing their gender based on the handwriting is examined, it can be roughly assumed that it is easier to recognise the gender of younger individuals who provided the samples (Figure 3).



Slika 3 *Graf raspršivanja uzoraka ovisno o točnosti pogodaka i dobi osobe koja je dala uzorak rukopisa*

Figure 3 *Scatter plot of samples based on guessing accuracy and the age of the handwriting sample provider*

This phenomenon becomes clearer when examining the average accuracy of each age group in relation to the age of the person who provided the handwriting sample. All age groups achieved the highest accuracy in guessing gender with handwriting samples from individuals aged 18-30 and the lowest accuracy with samples from those aged 51-80.

The average statistical accuracy of each age group in guessing gender based on handwriting from their own and other age groups is shown numerically in Table 1.

When the overall average accuracy of each age group in guessing gender based on handwriting is examined, there are no significant deviations; in other words, each age group has a similar overall average result (Figure 4).

The group of participants aged 18 to 30 had an overall average accuracy of 66.6%, the same as the group aged 31 to 50, while the group aged 51 to 80 had an overall average accuracy of 65.53%.

4.3. SPOL I TOČNOST U POGAĐANJU SPOLA PREMA RUKOPISU

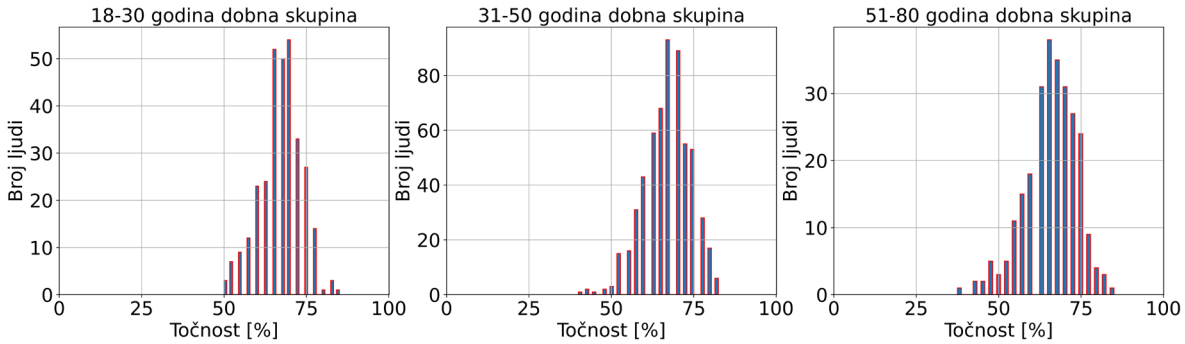
4.3. GENDER AND ACCURACY IN GUESSING GENDER FROM HANDWRITING

The study conducted by S. M. Newhall found that members of both sexes guessed gender from

Tablica 1 *Prosječna numerička točnost raspoređena prema dobnim skupinama te spolu ispitanika i rukopisa*

Table 1 *Average numerical accuracy distributed by age groups, as well as by the gender of the participants and handwriting sample providers*

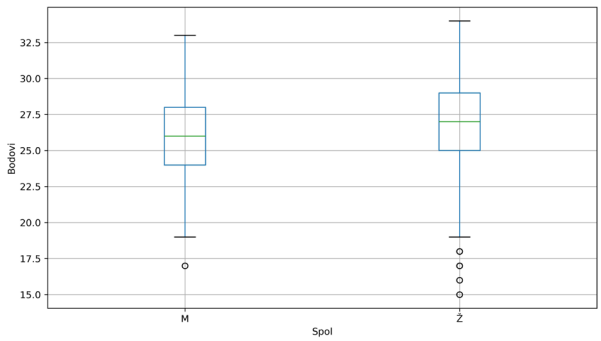
Age Group / Sex	Target Group	Average Accuracy (%)	Standard Deviation (%)	Statistical Error (%)
18-30	18-30	74,0	10,18	0,6
	31-50	67,7	10,57	0,6
	51-80	58,1	11,10	0,6
31-50	18-30	72,4	11,54	0,5
	31-50	68,3	10,72	0,4
	51-80	59,1	11,53	0,5
51-80	18-30	69,6	12,30	0,8
	31-50	66,2	11,31	0,7
	51-80	60,8	12,37	0,8
Sex (handwriting)	Women guessing female handwriting	64,5	10,90	0,4
	Women guessing male handwriting	69,9	10,21	0,3
	Men guessing female handwriting	62,7	10,33	0,8
	Men guessing male handwriting	68,4	10,29	0,8



Slika 4 *Ukupna prosječna točnost u pogađanju spola prema rukopisu svake pojedinačne dobne skupine*

Figure 4 *Overall average accuracy in guessing gender from handwriting for each individual age group*

handwriting with similar accuracy, with male participants achieving 56.94% accuracy and female participants 58.44% [3]. This 1.5% difference is comparable to the 1.65% difference found in this study. Male participants had an average accuracy of 65.55%, while female participants had an average accuracy of 67.2%. Figure 5 shows the relationship between scores and gender using a box plot.



Slika 5 *Kutijasti dijagram koji prikazuje medijan, netipične vrijednosti, gornji i donji kvartil i prosječan broj ostvarenih bodova u odnosu na spol*

Figure 5 *Box plot showing the median, outliers, upper and lower quartiles, and average score achieved in relation to gender*

Both sexes show slightly higher accuracy in recognising male handwriting. Male participants had an average accuracy of 68.4% when identifying the gender of male handwriting and 62.7% for female handwriting. Female participants, had an average accuracy of 64.5% for recognizing female handwriting and 69.9% for male handwriting (Table 1).

5. RASPRAVA
5. DISCUSSION

As indicated in earlier research—it appears that (with some margin of error) it is possible to recognise a person's gender based on their handwriting. Furthermore, the accuracy of gender recognition from handwriting has not changed significantly over time. In this study, the overall average accuracy for both sexes (66.84%) can be considered typical—earlier studies have reported overall averages for both sexes of 69.75% [1], 67.33% [2], 69.75% [13], 57.34% and 57,5% [3],77% [14], 77% [15], 67,84% [6], and 71,19% [4]. Another study examining accuracy in guessing gender from handwriting presented participants with a video shoeing the entire writing process (the video displayed, only the imprint left on the surface, not the author's hand), and the average accuracy in guessing gender was 63.88% [7].

Participants deciding whether a particular sample was written by a female or male most often look for handwriting elements they stereotypically associate with each sex [3]. Some participants who voluntarily described their thought process stated that they assumed a male author for messier handwriting and a female author for neater handwriting. Handwriting elements from earlier research stereotypically attributed to males include "boldness and carefreeness," while those attributed to females are "neatness, conventionality and minuteness" [2]. In a 2005 study, participants most often described typical male handwriting as "untidy," and female handwriting as "round and neat" [4]. Based on this, it can be assumed that handwriting gender stereotypes have remained unchanged over the past hundred years.

Earlier researchers noted that some handwriting authors exhibit "inversion in gender symbols,"

meaning their handwriting contains elements characteristic of the opposite sex. [3] This phenomenon is slightly evident in this study, as gender for 26 out of 40 handwriting samples was correctly recognised by 70% or more of participants or incorrectly recognised by 70% or more. Only 6 samples had the author's gender correctly recognised between 40% and 60%.

Sex-conditioned differences in handwriting may also be attributed to differences in typical work activities performed by men and women. Other explanations for sex-conditioned differences in handwriting include cognitive, behavioural, hormonal, and experiential factors that may influence handwriting. [11] Neurological differences that may also underlie differences in men's and women's handwriting—these have been observed in a part of the brain called "Exner's area," located above Broca's area in the left frontal lobe. Functional connectivity between Exner's area and the cerebellum differs between men and women, implying differences in "neural integration fundamental to handwriting". [12]

Hormones are also among the factors that could influence handwriting – it has been suggested that female prenatal hormones affect the "feminisation of handwriting," as well as gender recognition. Since the left hemisphere of the brain is more involved in handwriting production than the right, this difference conditioned by prenatal hormones manifests when writing with the right hand (because the right hand is connected to the left hemisphere of the brain). Some explanations for this phenomenon are that hormones influence motor skills (for example, slower writing may result in handwriting more often recognised as female) or that hormones inhibit or promote verbal development and sociability, resulting in better capacities for written and verbal communication (the so-called Matthew effect). Hayes in 1996 showed in one of his experiments that it is also possible, though with lower accuracy, to guess the gender of an author writing with the non-preferred hand (e.g., a left-handed individual writing with the right hand and vice versa), leading to the conclusion that both motor skills and cumulative practice of written expression influence handwriting. Analogous effects of male hormones on handwriting were not observed. [4]

This study showed that the gender of the person guessing the gender based on handwriting does not significantly affect the average accuracy of guesses, which aligns with earlier research from 2005 [4]; female participants showed only slightly higher accuracy in guessing gender by handwriting than male participants, a finding already noted in research from 1945. [13] It also appears that both sexes have slightly higher accuracy when guessing handwriting written by men. The overall difference between sexes in average accuracy of guessing gender based on handwriting obtained in this study (5.55%) is greater than in Newhall's study, which was 1.55% [3], but smaller than in Goodenough's study, which was 14.9% (it should be noted that this research was conducted on samples written by high school students, and participants in that study could express their confidence in the author's gender across three confidence levels or remain fully neutral, meaning they had seven possible answers per sample instead of just two). [13] Another study indicated a higher likelihood of correctly guessing the gender of male handwriting, with an average difference of 18%. [14] Since differences in accuracy of guessing male and female handwriting are implied but not conclusively established, further research should confirm or refute this theory.

Findings from similar research in 1991, conducted on seven- and eight-year-old children, showed different results: boys were better at recognising the gender of other boys based on handwriting, while girls were better at recognising the gender of other girls. When asked to write a text imitating the handwriting of the opposite sex, the situation changed – boys more accurately recognised the gender of girls' handwriting, and girls more accurately recognised the gender of boys' handwriting. [5]

Even if the age of the person who wrote the handwriting sample influences the probability of correctly guessing their gender, the age of the person guessing does not significantly affect recognition accuracy. No age group showed significant differences in overall accuracy or in accuracy when guessing the gender of any specific age group.

The connection between gender and handwriting

is now studied and analysed across many scientific disciplines. While historically it was mainly associated with psychology and criminology, new technological possibilities—especially machine learning—have broadened the scope of this phenomenon. One recent study determined the gender of a person based on handwriting with an accuracy of 88.10% for adults and 90.09% for children [9]. Some newer deep learning models, such as VGG and GoogLeNet, achieved exceptionally high accuracy of over 95% for both genders. [8]

There are large models supporting South Slavic languages in their functions [16], but a large model trained exclusively on South Slavic handwriting samples does not yet exist. Since South Slavic languages contain specific symbols like "č" and "ć," a model developed on handwriting samples from this region could significantly improve text recognition performance. This is also related to research analysing handwritten text, where pre-trained models trained on Albanian handwriting samples showed substantial improvements in recognition accuracy because of characteristic symbols in Albanian, such as "ë" and "ç". [17]

Moreover, there is a pronounced lack of research examining gender recognition from handwriting within populations of Balkan peoples. Further research in this area could confirm existing findings and determine whether the results obtained on these populations deviate on those of other populations.

The age of the handwriting author has proven to be a significant variable influencing the accuracy of gender prediction based on handwriting. The results of this study suggest that it is easier to assume the gender of younger handwriting authors. This hypothesis could be confirmed by a longitudinal study in which the same handwriting authors at different ages would provide samples for participants to guess the author's gender.

Besides age, future studies could classify handwriting from additional variables such as educational status, socioeconomic position, or IQ, and investigate whether these affect the accuracy of gender recognition based on handwriting. Previous research using machine learning methods suggests a strong link between handwriting and personality [18] , opening up further possibilities for analysing individual characteristics of authors based on handwriting.

Determining gender from handwriting has significant implications in forensic science, so it is not surprising that many important studies on this topic have been conducted of graphology and criminology purposes. Despite numerous forensic studies, there is still no methodology that can determine gender with absolute certainty in forensic handwriting identification, but the results of such research can be used in the process of criminal profiling of perpetrators [10].

6. ZAKLJUČAK
6. CONCLUSION

Gender and handwriting appearance are variables that undoubtedly correlate to some extent. Numerous previous studies on this topic have demonstrated both sustained interest in the issue and an actual connection between the two variables. The most frequently reported average results for guessing gender from handwriting range from 57% to 77%, and the average accuracy of gender identification obtained in this study is the midpoint of these extremes, namely 66.84%. Female participants achieve only marginally better results in guessing gender based on handwriting, but not significantly enough to assert a true link between gender and the ability to identify gender from handwriting. A stronger correlation is observed between the gender of the author and the probability that both sexes will correctly guess the author's gender—it appears that male authors' handwriting is easier to identify by gender (regardless of the guesser's gender), though this claim also requires further evidence and is not yet firmly established.

When the variables of the handwriting author's age and the guesser's age are included in the study, new conclusions emerge that may further explain human perception of handwriting. While the guesser's age does not appear to play a major role in the probability of correctly identifying the handwriting author's gender, the author's age likely does. Based on the results obtained in this study, it is concluded that all age groups are better

at guessing the gender of younger handwriting authors.

This is the first study of the statistical connection between gender and handwriting among South Slavic language speakers, and it is believed that the results, supported by further research, will make a significant contribution to understanding the relationship between gender and handwriting.

7. ZAHVALE

7. ACKNOWLEDGMENTS

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8. REFERENCES

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